CENTER FOR INSTITUTIONAL REFORM AND THE INFORMAL SECTOR

University of Maryland at College Park

Center Office: IRIS Center, 2105 Morrill Hall, College Park, MD 20742
Telephone (301) 405-3110 • Fax (301) 405-3020

MEDIATING RISK THROUGH MARKETS, RATIONAL COOPERATION, AND PUBLIC POLICY: INSTITUTIONAL ALTERNATIVES AND THE TRAJECTORIES OF AGRARIAN DEVELOPMENT IN THE WEST AFRICAN SAHEL

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Michael Carter and Frederic Zimmerman
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Authors: Michael Carter and Frederic Zimmerman, University of Wisconsin

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Mediating Risk Through Markets, Rational Cooperation, and Public Policy: Institutional Alternatives and the Trajectories of Agrarian Development in the West African Sahel

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The distribution of land in West Africa is and has traditionally been one of the most egalitarian in the world. Historically, that egalitarianism has undoubtedly been rooted in the extensive, land abundant, subsistence character of West African agricultural production. But as West African agriculture becomes more productive and as land becomes economically scarcer, will that egalitarian distribution survive and underwrite a socially smooth agrarian transition, or will risk and weak financial market structures conspire to generate and reproduce a polarized agrarian class structure?

To address this question, this paper employs a dynamic stochastic programming model. It builds directly on a companion paper (Carter and Zimmerman 1994) which argues that it is the nexus between risk and factor scarcity which creates the demand for the institutional innovation of a land market. This paper begins by analyzing the earlier work's implication that the structural implications of a risk-scarcity land market are anything but random. Under a stylized laissez faire scenario, this paper employs a dynamic stochastic programming model to show that the land market tends to polarize the land ownership distribution precisely because relatively minor differences in initial endowments map into different risk-coping capacities.

This paper then examines the prospects for a decentralized (but non-market) cooperative response to the risk-coping problem. The model is reanalyzed when agents have the option to participate in an informal risk-sharing network. The network is incentive compatible in the sense that agents can choose to exit the scheme subject to a termination incentive. Simulation of the model under this institutional scenario reveals that risk-sharing network breaks down over time and that the long term structural implications of the land market are largely unchanged from the laissez faire scenario.

These findings, that neither markets nor the rational cooperation of an incentive compatible reciprocity scheme suffice to stem a risk driven tendency for polarization in the land distribution, with its attendant efficiency and welfare consequences, underwrite the paper's primary policy conclusion: There is a strong preemptive case for governmental provision of risk management (e.g. a rainfall lottery) as part of any liberalization or agrarian development program.

Mediating Risk Through Markets, Rational Cooperation, and Public Policy: Institutional Alternatives and the Trajectories of Agrarian Development in the West African Sahel

Michael Carter
Associate Professor of Agricultural Economics

and

Frederic Zimmerman
Department of Economics

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Mediating Risk Through Markets, Rational Cooperation, and Public Policy:
Institutional Alternatives and the Trajectories of Agrarian Development in the West African Sahel

The distribution of land in West Africa is and has traditionally been one of the most egalitarian in the world. Historically, that egalitarianism has undoubtedly been rooted in the extensive, land abundant, subsistence character of West African agricultural production. But as West African agriculture becomes more productive and as land becomes economically scarcer, will that egalitarian distribution survive and underwrite a socially smooth agrarian transition, or will risk and weak financial market structures conspire to generate and reproduce a polarized agrarian class structure?

A paper related to this one (Carter and Zimmerman 1994) theoretically shows that land scarcity by itself is insufficient to induce the emergence of an active land market in a relatively egalitarian agrarian economy. However, when risk-coping is individualized, and when risk-coping capacity varies across individuals, there are incentives to create a land market in the sense that individuals would be willing to pay significantly for its creation. In contemporary West Africa, where formal financial markets are unlikely for a host of informational reasons to replace the social sharing of the dissolving customary social order, the interplay between land scarcity and risk seems likely to drive the endogenous emergence of the land market and to provide the basis for its operation.[1]

This paper adds two dimensions to this earlier work. First, it analyzes the earlier work's implication that the structural implications of a risk-scarcity land market are anything but random. Under a stylized *laissez faire* scenario, this paper employs a dynamic stochastic programming model

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[1] A provocative body of literature on the structure of land transactions in contemporary Africa suggests that while land sales are not common, where they do occur they often take the form of desperation sales in which smallholders lose access to land to better-endowed agents (Watts 1983; Bruce 1988; Tallet 1985).

to show that the land market tends to polarize the land ownership distribution precisely because relatively minor differences in initial endowments map into different risk-coping capacities. Second, this paper then examines the prospects for a decentralized (but non-market) response to the risk coping problem. The model is reanalyzed when agents have the option to participate in an informal risk-sharing network. The network is incentive compatible (or, "endogenously enforced" in Coate and Ravallion's terms) in the sense that agents can choose to exit the scheme subject to a termination incentive. Simulation of the model under this institutional scenario reveals that risk-sharing network breaks down over time and that the long term structural implications of the land market are largely unchanged from the *laissez faire* scenario.

The focus in this analysis on evolution of the land ownership distribution transcends direct concerns about income inequality--i.e., who gets the rent from land. There exists a vast body of theoretical and empirical literature which establishes what Abijhat Sen (1982) calls the "connectedness" between patterns of land ownership and patterns of resource allocation, employment generation and economic efficiency. By fully endogenizing land ownership structure, this study is able to more fully analyze the connectedness or consequences of land ownership distribution for the trajectory of market-mediated agrarian development. Its primary implications are not, however, a luddite opposition to the operation of markets. Instead, it identifies the space for an active policy role in providing risk management devices (e.g., a rainfall lottery) to supplement the intrinsic limitations of decentralized, market and non-market, responses.

Section 1 below presents the basic assumptions concerning technology, preferences, and the structure of risk. Section 2 presents a model of agricultural production and asset accumulation under the sort of environmental risk encountered in the West African semi-arid tropics. The dynamic, individual choice problem at the heart of the model portrays the tradeoffs between consumption and investment in a resource-poor environment. The value of such tradeoffs to specific agents depends fundamentally on the consumption risk to which they are exposed, where consumption risk reflects environmental risk only through the lens of technological and institutional factors. The objective of this model is to observe the extent to which a productive asset--in this case land--comes to serve as a store of value to be liquidated when adverse shocks severely reduce present consumption. Of particular interest is how a household's initial endowment enables it to acquire a surplus stock of stored grain, that, while not directly productive itself, relieves the pressure on land as a risk-coping asset.

This model then brings together the intertemporally rational decisions about land- and grain-accumulation and consumption of a large number of heterogeneously endowed agents who comprise a stylized village economy. Their resulting rational decisions to demand or supply land are interacted in a land market to generate an endogenous land price. This process of production, consumption and land market is repeated several times over to generate an endogenous evolution of the distribution of land over time. Throughout this evolution, agents have rational expectations about the stream of endogenous prices. Initially, the village economy is studied under an atomized or laissez-faire scenario. Production parameters, risk, and asset distributions are estimated from data collected in Burkina Faso. Results are presented in Section 3.

Section 4 extends this model by incorporating an incentive-compatible social sharing scheme meant to capture the possibilities of reciprocity-based informal risk-coping in the Sahel. Agents decide in every period whether they want to continue their participation in the social sharing scheme, but once they exit, they are forever denied access to the network, thereby endogenizing its value to the remaining participants. The coverage and value of the network evolve over time, and the model endows agents with rational expectations about this evolution. Section 5 presents the results of this reciprocity model and compares them to those of the more individualistic model. The paper's final section discusses the welfare and policy implications of this exercise.

Section 1 The Economic and Institutional Environment.

Institutional environment means not just the market institutions or lack thereof, but also all that conditions market access, market transactions, and the allocative decisions of the agents, including the representation of production risk, individual rationality, social-sharing schemes and other forms of risk-coping, and the functioning of the land, labor and capital markets. The model encompasses the collectivity of households within one village: the land and labor markets are closed to outsiders. The village will be defined so as to be coextensive with the local land and labor markets (an assumption which does little violence to the reality of West African markets), and it will consist of ninety-six households--a typical size for a Sahelian village[2].

The **asset-portfolio** of peasant households in West Africa is fairly circumscribed, and it is without over-simplification that there are just two assets in the model: land; and a composite, non-productive asset of stored grain, small livestock and cash.[3] The 96 model households will begin the simulation with a level of assets that is calculated based on the observed asset distribution in Burkina Faso.

Production in this model will be represented by a simple production function that represents output as a slightly diminishing-returns function of land.

Production risk is the product of two distinct shocks: an idiosyncratic shock, Θ_i, which captures those risks which affect household "i" only, such as health problems during the work season, localized flooding or erosion, localized rainfall irregularities and so on. Second, a village-level shock, Θ_v, represents primarily weather-related shocks that affect an entire village. In the model of

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[2]The exact number of households was chosen to be 96 for the arbitrary reason that it made distributing assets among simulation households according to the particular, empirical distributions slightly easier.

[3]Household labor could also be considered an asset to be accumulated, and an interesting extension of the model would model endogenous population growth.

consumption and asset accumulation, both covariate and non-covariate risks are important to the process of balancing short-term consumption vs. long-term investment. Because the model will be simulated numerically rather than solved analytically, risk is represented by a number of draws from a vector of a discrete number of possible risk outcomes. The risk structure is therefore modelled in the following way. In every period there will be one draw from the village risk vector: $\Theta_{vt} \in \{\Theta_{1v}, \Theta_{2v}, \Theta_{3v}\}$. Each individual will then get one draw from the individual risk vector, the variance of which depends on the draw of Θ_v. $\Theta_{it} \in \{\Theta_{1i}, \Theta_{2i}, \ldots \Theta_{9i}\}$. There are thus nine possible outcomes which the agent faces: $\Theta_{it} \cdot \Theta_{vt} \in \{\Theta_{1i} \cdot \Theta_{1v}, \Theta_{2i} \cdot \Theta_{1v}, \Theta_{3i} \cdot \Theta_{1v}, \Theta_{4i} \cdot \Theta_{2v}, \Theta_{5i} \cdot \Theta_{2v}, \Theta_{6i} \cdot \Theta_{2v}, \Theta_{7i} \cdot \Theta_{3v}, \Theta_{8i} \cdot \Theta_{3v}, \Theta_{9i} \cdot \Theta_{3v}\}$. The parameterization of this risk structure is presented in Appendix A.

1.1 Risk-Coping.

The production and risk parameters' specifications are parameterized so as to incorporate a maximum degree of private risk-coping (such as plot-scattering, intercropping, optimal planting). Formal insurance is non-existent[4].

Two main techniques of risk-coping remain. The first, asset management through grain and livestock accumulation, has already been touched upon. The second form of risk-coping involves village reciprocity networks. These **Social-sharing schemes** function by allowing members to pool idiosyncratic risk to keep everybody above subsistence. All agents begin the simulation participating in a scheme that redistributes food from all those with reserves above subsistence requirements to those with insufficient reserves. In the event that those with extra grain have more than enough to

[4] Remittances from migrant relations are another important form of risk-coping in West Africa. They are excluded from the model, however, because there are no firm data on how much these transfers are, and because they are highly correlated with farm size and other assets (Saul 1988). Only larger, more prosperous farms are in general able to afford the education, transportation and initial period of low wages necessary to successfully install a family member in the city. As Saul (1988) points out, "people don't migrate to eat, they migrate to get rich."

bring all the poor up to subsistence, the rich contribute to the poor in proportion to their own surplus. There is no explicit obligation on the part of the poor to pay back what they have taken, only an understanding that in subsequent years they may be called upon to contribute to others, on the basis of a future surplus. Although such a scheme may not be actuarially fair for all the participants, it does fit the West African reality fairly well (Capron 1973; Coquéry-Vidrovitch 1985; Baudoin 1975). Those whose asset base permits them to pursue other forms of risk-coping (especially conditional self-insurance through asset-management) may withdraw from the social sharing scheme. As they do so, the value to the remaining participants will evolve as the risk pool changes. The provision of this possibility captures the threat to customary risk-coping when a few of the wealthiest withdraw, leaving behind those with smaller asset bases. The value to a given agent of participation accordingly evolves endogenously as the simulation progresses, for two reasons. As the composition of the sharing pool changes as some people withdraw, the mean net benefit changes, as does the variation around this mean. Agents formulate rational expectations about these developments: their expectations differ from realized values by no more than some random, unbiased disturbance.

1.2 Subsistence Minimum

Part of the vital importance of risk derives from the fact--not well captured in economic models of consumption behavior or utility maximization--that people must consume a minimum amount on a regular basis just to survive. The model employs a standard utility function that is aggregated linearly over time. To capture this biological (or social) subsistence requirement, it is assumed that there is a subsistence minimum (to be called R_0) which agents must consume in every period. Agents who cannot meet this requirement out of stored grain, livestock and current production will alienate their other asset, land, to the extent necessary to meet subsistence.

This subsistence constraint is included because without it, poor agents would find it rational to consume at extremely low levels for some number of periods while they build up their asset levels. Clearly such hyper-self-exploitation would in reality lead to a genuine physiological crisis.

Section 2 An Intertemporally Rational Model of Land and Grain Accumulation in the Risky Agricultural Environment of the Sahel.

Agents maximize expected, infinite-horizon utility:

$$\underset{\{\underline{c}_o,\underline{T}_1,\underline{M}_1\}}{Max} \; E_o\{\, U \sum_{t=1}^{\infty} \delta^t u(c_t)\} \qquad (1)$$

$$\underline{c}_s = \{c_s, c_{s+1}, c_{s+2}, ...\}$$
$$\underline{T}_s = \{T_s, T_{s+1}, T_{s+2}, ...\}$$
$$\underline{M}_s = \{M_s, M_{s+1}, M_{s+2}, ...\}$$

$$\text{s.t. } c_t \leq F(T_t, \Theta_{it}, \Theta_{vt}) + \mu M_t - P_{Tt}(T_{t+1} - T_t) + (M_{t+1} - M_t) \qquad (2)$$

$$F = \Theta_{it}\Theta_{vt}D\cdot(T_t)^{\sigma} \qquad (3)$$

$$c_t \geq \min\{\, R_0,\, F(T_t, \Theta_{it}, \Theta_{vt}) + P_{Tt}T_t + M_t \,\} \qquad (4)$$

given T_o, M_o, Θ_{io}, Θ_{vo}

where:

Θ_{it}	idiosyncratic shock to individual i in period t.	Θ_{vt}	a village-level shock in period t
D	land productivity parameter	T_{it}	is i's land stock in period t
F_{it}	i's production in period t		
ß	labor productivity parameter		
σ	output elasticity parameter	μ	average growth of livestock divided by avg. fraction of livestock in non-productive asset
M_{it}	stored grain and livestock		
P_{Tt}	land price in period t		

Maximizing the infinite-horizon problem involves calculation of a true value function within the context of a dynamic programming model.

2.1 The Dynamic Programming Model.

The key tradeoff to be captured in this model is that between present consumption and asset accumulation for future consumption. Doing so is straightforward because the infinite-horizon maximization problem (1) is additively separable in time, breaking into two parts representing present and future consumption:

$$E_o\{ \underset{\{c_o,T_1,M_1\}}{Max} \sum_{t=0}^{\infty} c_t^e \delta^t \} = \underset{\{c_o,T_1,M_1\}}{Max} \{c_o^e + \delta \, E_o \{ \underset{\{c_1,T_2,M_2\}}{\max} \{\sum_{t=1}^{\infty} c_t^e \delta^t | given T_1, M_1\}\}\} \tag{5}$$

$$s.t. \;\; (2) \;,\; (3) \;\; and (4) \;\; \forall \; t$$

$$given T_o, M_o, \theta_{io}, \theta_{vo}$$

A value function (J(T,M)) can therefore be defined:

$$J^*(T_o,M_o) = E_o\{ \underset{\{c_o,T_1,M_1\}}{\max} \sum_{t=0}^{\infty} c_t^e \delta^t \} \tag{6}$$

Here $J^*(T_o,M_o)$ is the maximum expected discounted present value to be obtained from the asset combination (T_o,M_o). Besides being defined over the domain of land and grain stocks, the true value function depends on all the functional parameters of the model, including the distributions of Θ_i, Θ_v. (Because the true value function expresses expected value, it does not depend on particular realizations of Θ_{it}, Θ_{vt}.)

The infinite-horizon maximization problem (1) now simplifies to:

$$\max_{\{c_o,T_1,M_1\}} \{ c_o^{\epsilon} + \delta J^*(T_1,M_1)\} \tag{7}$$

$$s.t.\ \ (2)\ ,\ (3)\ \textit{and}\ (4)\ \ \textit{for}\ t = 0$$

$$\textit{given}\ T_o, M_o, \theta_{io}, \theta_{vo}$$

A true value function, J*, self-confirms its optimality (Bellman's equation):

$$J^*(T_o,M_o) = E\{ \max_{\{c_o,T_1,M_1\}} \{ c_o^{\epsilon} + \delta J^*(T_1,M_1) \} \} \tag{8}$$

If the model were purged of all production risk, the holding of wealth stocks would not play their role as a risk buffer, and so would not impinge on the utility value of consumption to be got from agricultural production. The value function would therefore be additively separable in its arguments: $J(T,M) = J_1(T) + J_2(M)$. The first derivatives of J_1 and J_2 would be continuous and monotonic. These modifications would lead to an analytically tractable value function, which would imply straightforward accumulation trajectories for all the agents. Under the production risk specification, however, the value function represents a convolution of many random variables. Numerical estimation is therefore used to determine the true value function.

2.2 *Estimating the True Value Function.*

The task of determining the true value function is as conceptually simple as it is computationally intense. First, a lower value function is posited, $J_0(T,M)$, which is a known underestimate of $J^*(T,M)$ over a grid of points in (T,M) space. For any given stochastic outcome

$\Theta_{io} \cdot \Theta_{vo}$, this J_o can then be updated for all values of T_o and M_o by applying Bellman's operator:

$$J_o'(T_o,M_o|\theta_{io}\cdot\theta_{vo}) = \max_{\{c_o,T_1,M_1\}} \{c_o^{\epsilon} + \delta J_o(T_1,M_1)\} \tag{9}$$
$$s.t. \;\; (2),\ (3)\ and\ (4)$$
$$given \;\; \theta_{io}\cdot\theta_{vo}$$

(Note that the form of the value function does not depend on time: the "o" subscript refers to the fact that J_o is an underestimate.)

The conditional updated value function J' depends on $\Theta_{it} \cdot \Theta_{vt}$ because the value of the constraints (2), (3) and (4) depend on the specific realizations of the stochastic shocks. The objective of the iteration process is of course the unconditional value function, which expresses expected present value of utility from a given asset base. The unconditional value function is obtained by summing the conditional value functions over the set of stochastic shocks, and weighting by the appropriate probabilities[5].

$$J'_o(T_o,M_o) = \sum_{n=1}^{3}\sum_{m=1}^{3} J'_o(T_o,M_o|\theta_{\epsilon}\theta_{vm})\cdot Pr(\theta_i=\theta_{\epsilon}|\theta_v=\theta_{vm})\cdot Pr(\theta_v=\theta_{vm}) \tag{10}$$

Since J_o is everywhere a (pointwise) underestimate of the true value function, and since it finds the maximum value--in terms of consumption and accumulation--over its domain, J_o' will always be at least as large as J_o. By repeated applications of Bellman's operator, J_o' eventually converges to

[5]Mathematically, summing across appropriately weighted stochastic outcomes is no different than summing across appropriately discounted time periods.

the true value function, J^* (Streufert 1990). However, since the $J_o(T,M)$ are numerical entities, it may not be obvious when they have converged to a limit. For this reason, Bellman's operator is also used to update an upper value function $J^o(T,M)$, a known overestimate of $J^*(T,M)$. Again, because J^o is (pointwise) higher than the true value function, successive applications of Bellman's operator will bring J^o down toward $J^*(T,M)$. When $J_o(T,M)$ and $J^o(T,M)$ differ by less than some epsilon for any (T,M) combination, then $J^*(T,M)$, which is always between the upper and lower value functions, has been identified to within that epsilon.

2.3 Biconvergence

For this search for a fixed point in value function space to yield the true value function with certainty, the utility function and the production function must together constitute a dynamic problem that is biconvergent. In essence, upper-convergence means that if the largest feasible consumption possibilities are pushed ever further into the future, they matter ever less to present utility. Lower-convergence means that as the lowest feasible consumption possibilities are pushed ever further into the future, they would matter less and less. Upper-convergence and lower-convergence together constitute biconvergence (see Streufert, 1990). Biconvergence guarantees that the transversality condition is met, and that a solution to Koopmans' equation is the same as a solution to the infinite horizon utility maximization problem (i.e., that equation (5) holds). The proof of biconvergence is straightforward, and is presented formally elsewhere. Lower-convergence holds automatically because of the form of the utility function. The intuition behind the proof of upper-convergence is that since the profit function under ideal factor allocation is decreasing returns to scale, satiation (in the utility function) and impatience (in the discount rate) imply that agents will not want to infinitely accumulate land or wealth.

2.4 *Evolving variables.*

Because the value function depends in large part on accumulation possibilities from given points, which are in turn dependant both on land prices and the value of the social sharing arrangement, and because these quantities evolve over time, the value function is not stationary. Strictly speaking, the value function is defined over $(T,M,\underline{\mathbf{X}}_t)$. The variables $\underline{\mathbf{X}}_t$ include four evolving, endogenous, price-like variables per period. On the one hand, there are the expected land price evolution and the expected evolution of the value of the social sharing arrangements from period t forward. On the other hand, there are the higher moments of the distribution of errors around these expectations.

The expected value of the land price and of the value to the agent of the social sharing scheme are important for obvious reasons. The variance of the disturbance away from these expected values is also important, however, because higher variances--i.e., potentially less precise expectations--induce greater consumption risk to the agent. The land price, for example, may be expected to be lower than its expected value when a negative (below-normal) village-level shock is realized. Agents understand the covariance between land price and village shock, however, and so are able to optimally diversify away from land and into grain as a risk-buffering asset. Similarly, the value of the social sharing scheme in any given period will be correlated with the village-level shock, a fact which will to some degree reduce its effectiveness as a risk-coping institution.

For any given period, the stream of price-like variables $\underline{\mathbf{X}}_t$ from that period onward can be taken as exogenous to the maximization problem, and hence to the determination of the true value function. In every period, however, the true value function must be re-estimated to account for the new expectations of $\underline{\mathbf{X}}_t$.

2.5 *Expectations.*

Agents are assumed to have rational expectations, meaning that they rationally calculate E[$\underline{\mathbf{X}}_t$ | Wt], where Wt is the information set available in time t. This assumption is operationalized by running the simulation a number of times over. When the price path from one run of the simulation conforms to expectations of it to within an unbiased, random error term, price expectations are taken to be rational. Agents are also assumed to be rational about the second moment of prices, i.e., the departure of the land price from the expected land price that is induced by the village-level shock. Clearly in bad years, with a low village shock, there is increased pressure for land sales, and the price will depart negatively from expectations. Conversely, in a good year, the land price should depart positively from expectations. Agents assume that this departure is invariant over time, and independent of whether the village-level shock is greater or less than the mean. Of course for the Laissez-faire model, expectations of both the value and the mean of the value of the social sharing arrangement are zero for every period.

Section 3 Results of the Laissez-Faire Model.

Using ICRISAT data from Burkina Faso, the model was parameterized, and asset distributions were estimated (see Appendix A) for 96 households representing a village economy. In a base-case, laissez-faire model, it is assumed that households undertake both production and consumption in isolation from one another.

In each period, a village-level shock is randomly selected (from the distribution in Appendix A--again estimated from the ICRISAT data), and each of the 96 households experiences a randomly selected idiosyncratic shock. These shocks interact with land-holdings and stored grain stocks to determine that period's disposable income for each of the households. Using the true value function, and against a called price for land, households maximize the expected present value of their utility over the choice variables of consumption and change of asset position. The interactions of household's net demand (positive or negative) for land determines village-level excess demand. A new land price is called to reduce this total excess demand, agents re-maximize, and so on, until the land market clears, at an endogenous price.

This process is repeated for 15 periods, until the resulting structural trajectory becomes clear, and structure approaches a steady state.

3.1 *Rational Expectations and Prices.*

Figure 1 presents the land price, as well as the expectations of it that were used to generate its development. As can be seen, prices conform to expectations quite closely throughout the simulation. Table 3 shows the deviation of the land price from its expected value, in percent (period 1 is omitted because the expected value of the first period land price does not enter into agents' decisions at any point of the simulation). The expected deviation of the price from expectations due to a village-level shock is 2%. Table 3 shows that this quite modest expectation of the risk-driven price variation is entirely within reason.

Table Three: Shocks and Sales

Period	Village Shock	P_t-E{P_t}	% of sales in in desperation	% of sales with adverse shocks
1.00	1.00		49	30
2.00	1.00	-3.33	10	27
3.00	1.00	3.03	15	30
4.00	1.25	1.78	14	31
5.00	1.25	1.58	16	34
6.00	1.00	0.00	22	35
7.00	0.75	-0.35	26	38
8.00	1.00	-0.87	25	39
9.00	1.00	-0.69	27	39
10.00	1.00	0.00	29	42
11.00	1.00	0.69	30	47
12.00	1.00	0.52	30	48
13.00	0.75	-0.52	36	49
14.00	1.00	-0.69	42	54
15.00	1.25	0.00	34	55

The land price increases steadily for the first five periods of the model, and then flattens out to a steady level for the remaining 10 periods.

3.2 *Evolution of Social variables*

Figure 1: Expected and Observed Evolution of the
Land Price: Laissez-Faire Case

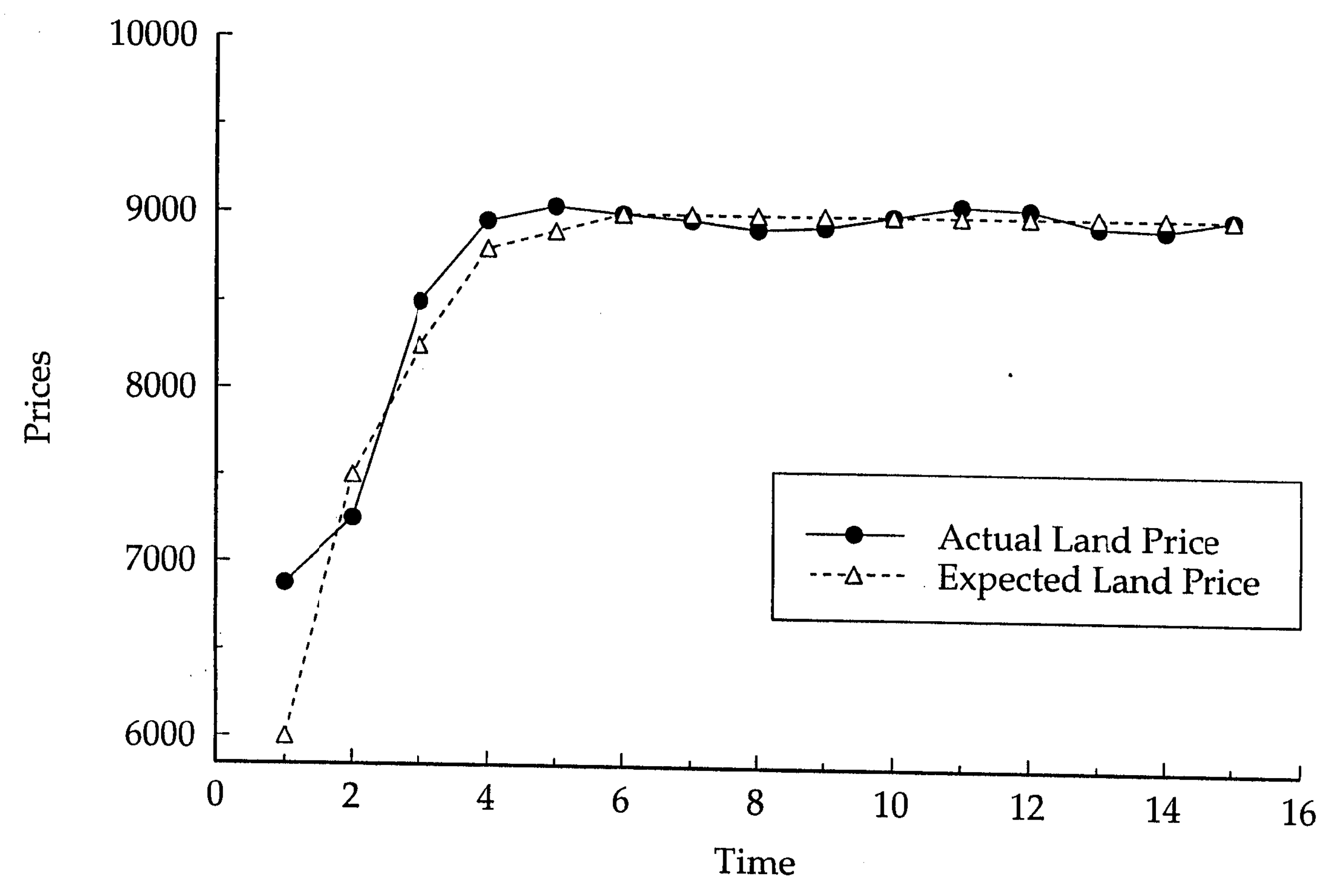


Figure 2: Evolution of Poverty and Inequality:
Laissez-Faire Case

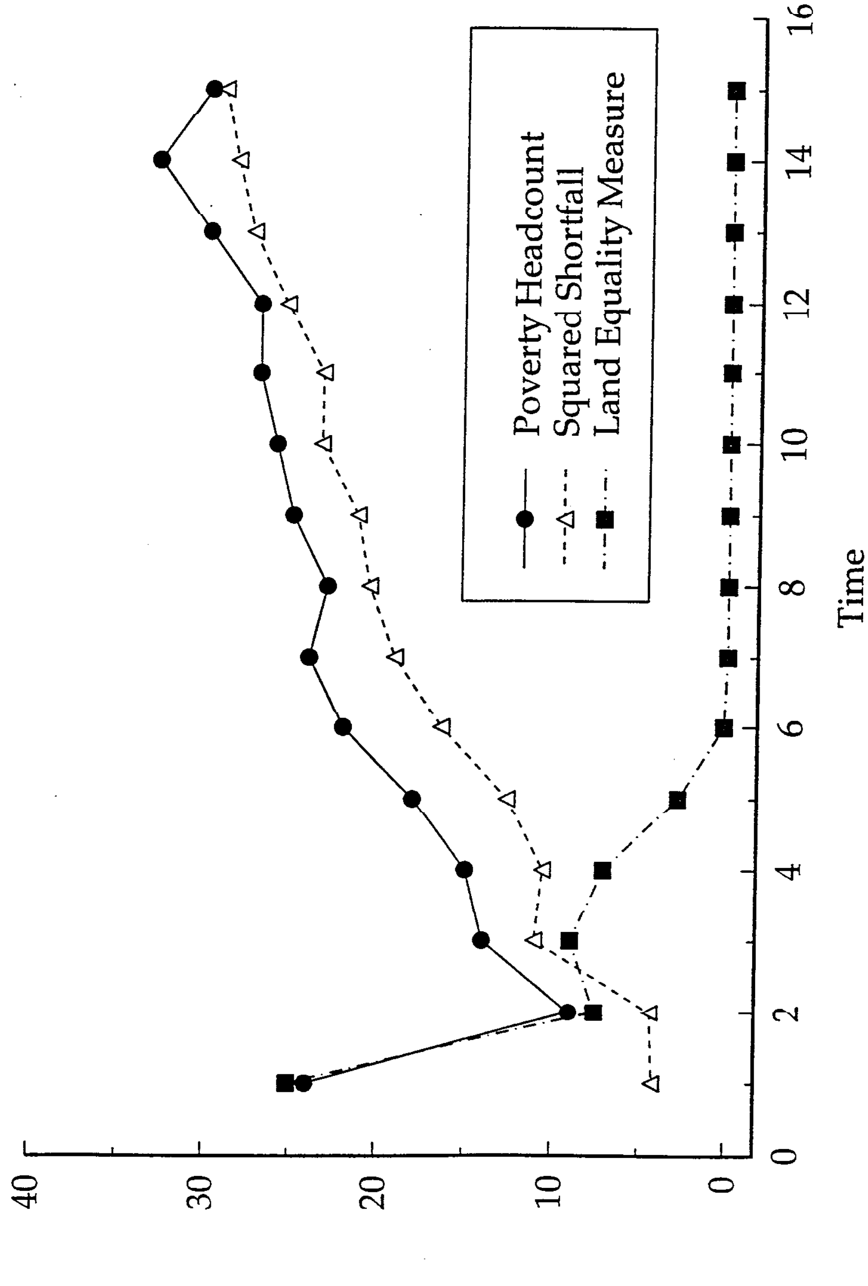


Figure 2 shows the evolution of poverty and inequality throughout the course of the simulation. The poverty headcount is the percentage of people in any given period whose consumption falls below subsistence. The squared subsistence shortfall is calculated by summing the squares of the amount by which the consumption of the impoverished agents falls below subsistence. It is included as a measure of the structure of poverty among the poor: a comparatively small number of very poor people will drive up this index more quickly than a larger number of people who consume at levels just barely below subsistence. The equality measure is one-thousand times the ratio of the land held by the poorest quintile to that held by the wealthiest quintile. Poverty marches steadily upward throughout the simulation, while the equality measures a marked decline early on.

The poverty headcount measure and the squared shortfall measure begin the simulation far apart, a reflection of the fact that in the initial distribution of assets there are a large number of households (approximately 24%) whose resources are inadequate to meet subsistence--but only by a small margin. In the first couple of periods of the simulation, many of these agents are able to improve their asset bases enough to lift themselves out of poverty, but are unable to maintain this higher asset base as the simulation progresses. The squared shortfall measure begins to rise rapidly after an initial shakeout period in which the poorest agents alienate land, and the land equality measure drops to zero after period six.

Additional insight into these developments can be gained by characterizing the participants in the land market by their position vis-à-vis the subsistence constraint. Figure 3 portrays the evolution of the proportion of agents in four distinct food security regions, defined as follows:

- A steadily rising fraction of the agents (35% by the end of the simulation) face an immediate subsistence crisis, meaning that even under the best of stochastic outcomes their resources, including production and stored grain, will be insufficient to meet subsistence requirements in this period. These agents accordingly face the certain necessity of having to sell off land to meet subsistence.

- The smallest group of agents are those for whom the probability of having to sell land to meet subsistence is greater than zero but less than one. Agents who begin the simulation in this position, i.e., that of "threatened" land-holdings, quickly migrate to other regions, chiefly that of the less dire "grain-threatened," as they optimally adjust their endowment portfolios by accumulating land and/or grain.

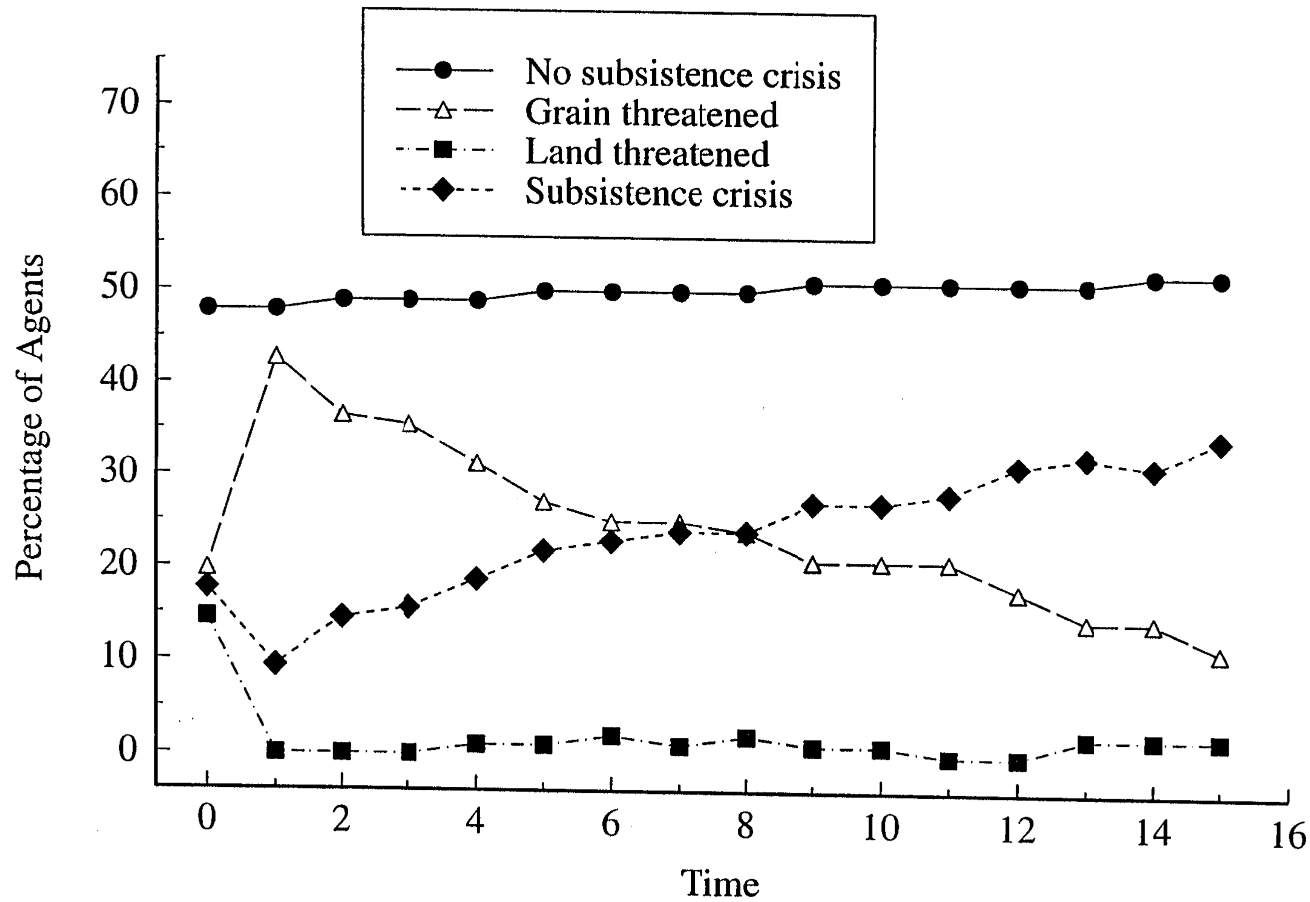
- A large fraction of the agents--as much as 40%, but declining to 15% by the end of the simulation--are "grain-threatened," meaning that there is a non-zero probability that an adverse combination of shocks will oblige them to eat more grain and farm produce than what they can produce in a year. Their stocks of grain are moreover in danger of being drawn down year after year if they were to experience a series of adverse shocks.

- Nearly 50% of the agents have sufficient quantities of land and grain stocks to protect them from a subsistence crisis even under the worst combination of village-level and idiosyncratic shocks. Their numbers are added to little by little as some agents from the "grain-threatened" region are able to accumulate sufficient quantities of land to put them beyond the reach of dangerous adverse shocks.

Carter and Zimmerman (1994) discuss in some detail the different relationships these types of agents have to the land market. The agents who face an immediate subsistence crisis sell land simply to meet a physiological requirement; their supply of land to the market is accordingly downward-sloping, with unit elasticity. The agents whose grain stocks are threatened by a possible subsistence crisis use both land and grain to buffer themselves against risk. While grain is the preferred risk-buffering asset for most of these agents, Carter and Zimmerman find that for certain ratios of land to grain asset portfolios, agents can in fact use land to smooth consumption over risky production outcomes. Only a small fraction of the agents in fact apply this strategy, however, and most agents accumulate sufficient grain to enable them to use grain instead as a risk buffer. This fact is significant for the evolution of prices. If many agents were to use land as a risk buffer, its price would be depressed in years in which there were an adverse village shock, thereby considerably reducing its attractiveness as a risk buffer. Because agents know this, they choose instead to accumulate a sufficient buffer of grain.

Agents who face no subsistence threat participate in the land market strictly for reasons of relative economic productivity. Because the production technology displays slightly decreasing

Figure 3: Agents in Various Food Security Regions:
Laissez-Faire Case



returns to scale, larger farmers will want to sell land to smaller farmers so that they can realize through its sale price a portion of the higher returns of small farms.

At the beginning of the simulation, the land price is low as farmers with unsustainably low amounts of land sell off to meet short-term subsistence requirements. Table 1 shows that in the first period, 49% of land sales (by quantity sold) are by farmers facing a subsistence crisis. Immediately thereafter, land sales become dominated by structural shifts induced by the decreasing returns technology. The land price continues to be low, however because of missing capital markets, which force the purchase of land to be financed out of surplus from production and stored grain. These sources are not only limited, but, as articulated above, play an important role as risk-buffering assets. The low land price of the initial periods reflects the relatively high shadow price of the safer asset, grain. As this asset is accumulated, the shadow price of risk-coping falls, and the land price rises.

Section 4 The Social Sharing Scheme

This section models a self-funded social sharing network that allows agents to band together to mitigate some of the risk to which their environment exposes them. Participating agents will receive a consumption supplement in the years in which their income and consumable assets (stored grain, livestock) are insufficient to meet subsistence needs (R_0), and will pay in a portion of their surplus production over subsistence in the years in which they do comparatively well. This sharing scheme will be run as a pool to which all agents belong at the start of the simulation. Agents may quit at will, but, having quit, are not eligible for reinstatement in the scheme. The payments will be determined by an honest fund manager according to a few simple rules, and are not subject to negotiation. Agents will pay their dues, or be judged to have quit and not be entitled to further compensation. Exogenous enforcement of the participants is ensured by an Authority, who may be thought of as the village headman, a council of elders, or the long arm of gossip.

The rules of the scheme are simplicity itself: those whose resources (production plus consumable assets) exceed subsistence requirements contribute in proportion to their wealth to bring those who are less fortunate up to subsistence level, or, if the funds of the well-off are not up to measure, the rich contribute to the poor until they have depleted their own funds to subsistence level. Expressed formally:

let H_n be the set of participants in the scheme

let H_p be the set of participants for whom

$$\theta_i \theta_v D(T_i)^\sigma + M_i < R_0$$

let H_r be the complement of H_p in H_n

let N_p, N_n, N_r be the number of agents in H_p, H_n, H_r respectively.

let T_n and M_n be the total of land and consumable assets for all participants

The outcomes can be divided into two cases:

<u>Case One: Sufficiency.</u>

$$\begin{aligned}
&\textit{If} \sum_{i \in H_n} (\theta_i \theta_v D(T_i)^\sigma + M_i) \geq N_n R_0 \\
&\textit{then} \;\; S_t = N_p R_0 - \sum_{i \in H_p} (\theta_i \theta_v D(T_i)^\sigma + M_i) \qquad (\textit{SocialTransfer}) \\
&\textit{and} \;\; K = \frac{S_t}{\sum_{i \in N_r} (\theta_i \theta_v D(T_i)^\sigma + M_i) - N_r R_0} \qquad (9)
\end{aligned}$$

The variable K is a wealth transfer parameter, the proportion of resources above subsistence which the wealthy will have to transfer to the poor to bring them up to subsistence. All wealthy people who participate in the social sharing scheme contribute the same proportion of their surplus to the poor.

When K is one, the wealthy consume only R_0, giving away their entire surplus. When K is zero, there are no claims on the surplus of the wealthy. Those whose resources exceed subsistence have as their consumption

$$c_i = R_0 + (1\text{-}K)(\Theta_i\Theta_v D(T_i)^\sigma + M_i - R_0) - P_T(T_{t+1}\text{-}T_t) - (M_{t+1}\text{-}M_t) \qquad (10)$$

And those whose resources are insufficient will consume subsistence: $c = R_0$.

Note that it will be impossible for the needy to divert funds to asset accumulation or for the wealthy to shield income by purchasing land. (Time subscripts have been omitted where doing so will contribute to clarity.)

Case Two: Insufficiency.

$$\textit{If} \ \sum_{i \in H_p} (\theta_i \theta_v D(T_i)^\sigma + M_i) < N_p R_0$$

$$\textit{then} \ \ S_t = \sum_{i \in H_r} (\theta_i \theta_v D(T_i)^\sigma + M_i) - N_r R_0 \qquad (\textit{SocialTransfer})$$

$$\textit{and} \ Q = \frac{S_t}{N_n R_0 - \sum_{i \in H_n} (\theta_i \theta_v D(T_i)^\sigma + M_i)} \qquad (11)$$

The variable Q is the poverty subsidy parameter. It represents the fraction of poor people's shortfall can be met by transfers from the wealthy. It will always be one when the social sharing scheme as a whole has aggregate resources in excess of aggregate needs. If there is no one in the social sharing scheme whose resources exceed subsistence, the poverty subsidy falls to zero. Because Case Two (Insufficiency) implies that total resources are less than total needs, consumption of the wealthy is just subsistence. The poor take from the wealthy in proportion to their need:

$$c_i = \Theta_i\Theta_v D(T_i)^\sigma + M_i + Q \cdot (R_0 - \Theta_i\Theta_v D(T_i)^\sigma - M_i) \qquad (12)$$

In each period, the agents compare the value to themselves of continuing participation in the social sharing scheme, with its lower bounds on consumption of the poor, and proportional tax on the rich, to the value of withdrawing from the social sharing scheme. In practice this is done by means of the true value functions, which of course are different with and without participation in the social sharing scheme. If the value taken by the true value function for a particular agents' asset combination (T,M) is higher without social sharing than with it, then that agent will withdraw from the scheme.

The households' values for consumption are only expected values ex-ante, depending as they do not only on village-level shocks and the shock to the individual making his/her decisions, but also (for those in the social sharing scheme) on the individual shocks of everyone in the economy. In assessing the expected value to the agent of the social sharing scheme, therefore, he or she will be interested in the distributions of the poverty subsidy (Q: eq'n 8) and the wealth transfer (K: eq'n 10). These variables are functions of $3N_n + 1$ random variables: Θ_v; N_n Θ_i; N_n T_i; and N_n M_i. While the T_i and M_i come from a deterministic process, they are based on disposable income, which is stochastic, and hence are not knowable several periods in advance. Moreover, the distributions of T_i and M_i are likewise unknown (indeed, they are the very variables of interest in this research). The resulting intractability of the poverty subsidy and the wealth transfer can be expressed as two problems: Given the large number of random variables involved, how can the distributions of Q and K be calculated, even if the distributions of the underlying variables were known? Second, what can be assumed about how people form expectations about the evolution of Q and K? If T_i and M_i were distributed according to a function of known analytical form, then an analytical solution would be conceivable for at least the mean and variance of Q and K. Since the form of their distributions is not known, however, a numerical approach is pursued.

The expected values of the poverty subsidy and the wealth transfer with respect to the individual's own shocks are transparent, as there are only nine possible outcomes. However, to find these variables over the outcomes of everyone else in the social sharing scheme involves adding up $9 \cdot 3^{N_n}$ different outcomes. Such a calculation would slow down the simulation to an impractical level. Instead, the aggregate effects of shocks to other agents in the social sharing scheme are represented by a smaller sample of agents, systematically selected to be representative of the sample. The mean and variance of an individual's expected transfer from the social sharing scheme can then be determined by reference to how shocks to the representative sample affect the value of the scheme as a whole.

The approach taken in modelling agents' expectations is to run the model several times, each time allowing the realized progression of Q and K for one run to serve as the expected progression of Q and K for the next. The eventual convergence of the realized progression and the actual progression constitutes a rational expectations equilibrium.

Section 5 Results of the Social Sharing Scheme Model.

The social sharing scheme model was simulated using the same parameterization and initial distribution as for the laissez-faire simulation. Figure 4 presents the evolution of the land price and its expectations, and Figure 5 shows the evolution of the social transfer variables and their expectations. Although the land price and the social transfer variables do not conform to expectations as closely as for the laissez-faire model, the convergence is sufficiently close to permit a useful comparison to the laissez-faire case.

Figure 6 depicts the progression of the proportions of agents in the various food security regions discussed above. Because an agent's categorization into one or another food security region depends only on his or her asset holdings, and not upon consumption, these values do not reflect the influence on the social sharing program, except as it prevents agents from falling into the region of land and wealth space in which subsistence crises are inevitable. In this respect an analysis of Figure 6 suggests that the social sharing arrangement is at best only modestly successful at preventing desperation sales. Indeed, over the entire course of the simulation, the proportion of agents whose assets are not sufficient to guarantee subsistence is no greater than it was under the laissez-faire

Figure 4: Actual and Expected Land Prices
Social Sharing Scheme

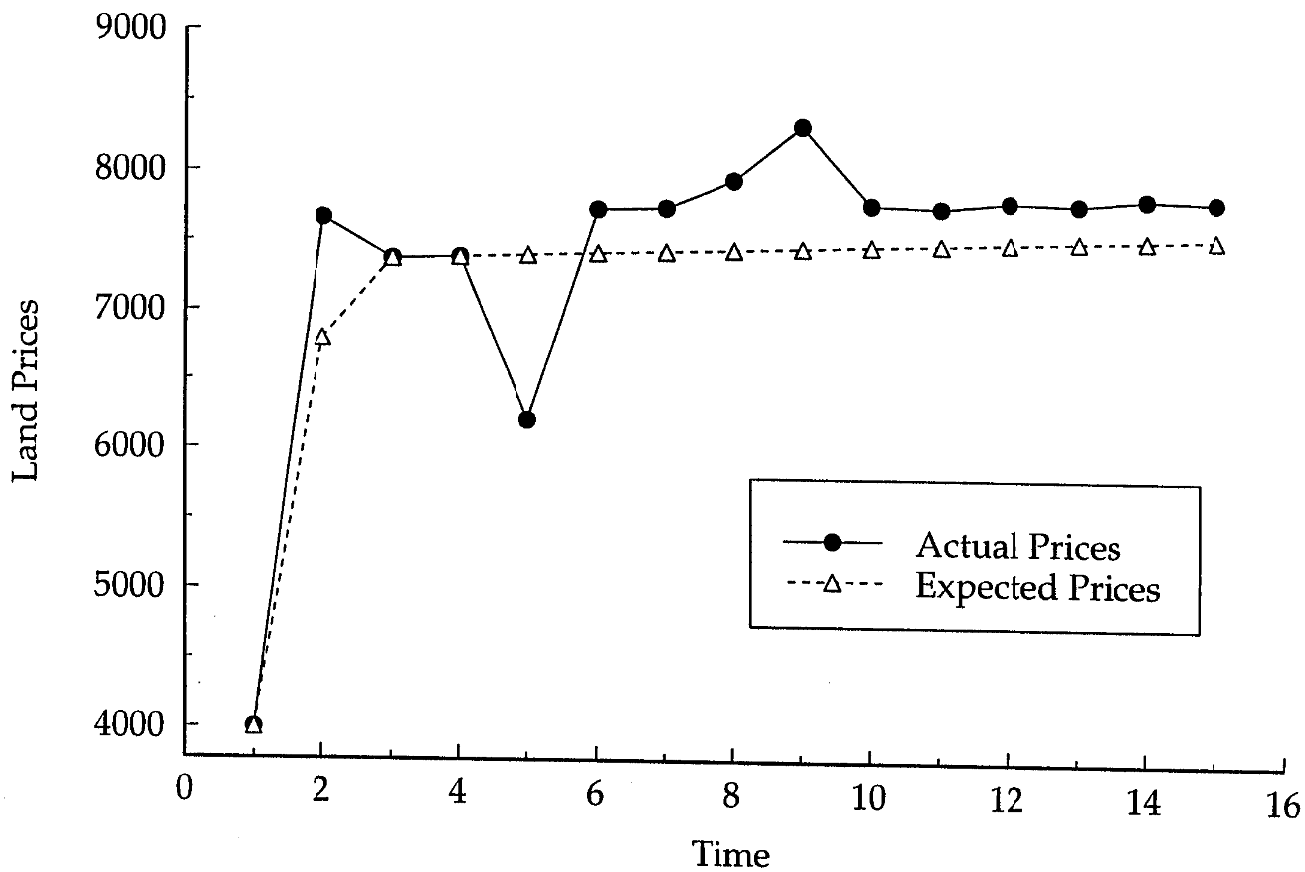


Figure 5: Evolution of Social Transfers

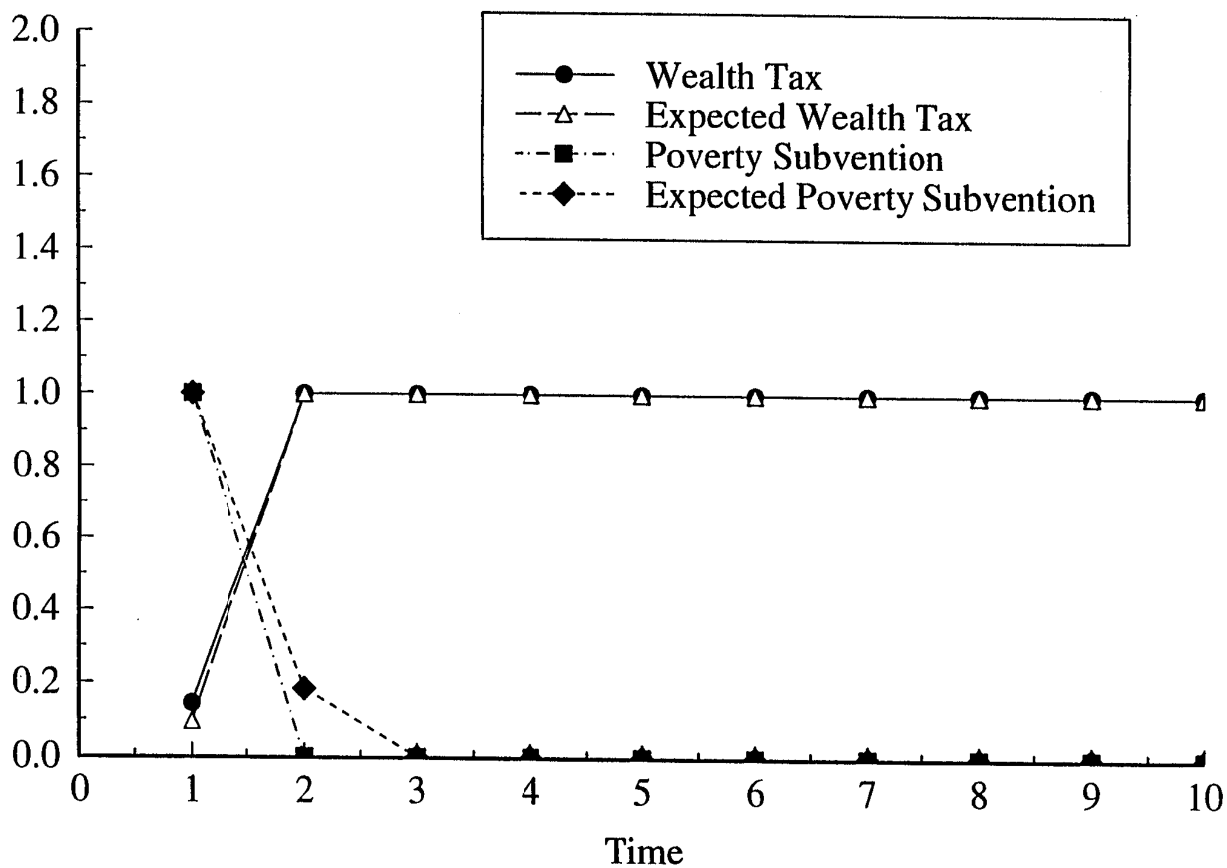


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Figure 6: Agents in Various Food Security Regions

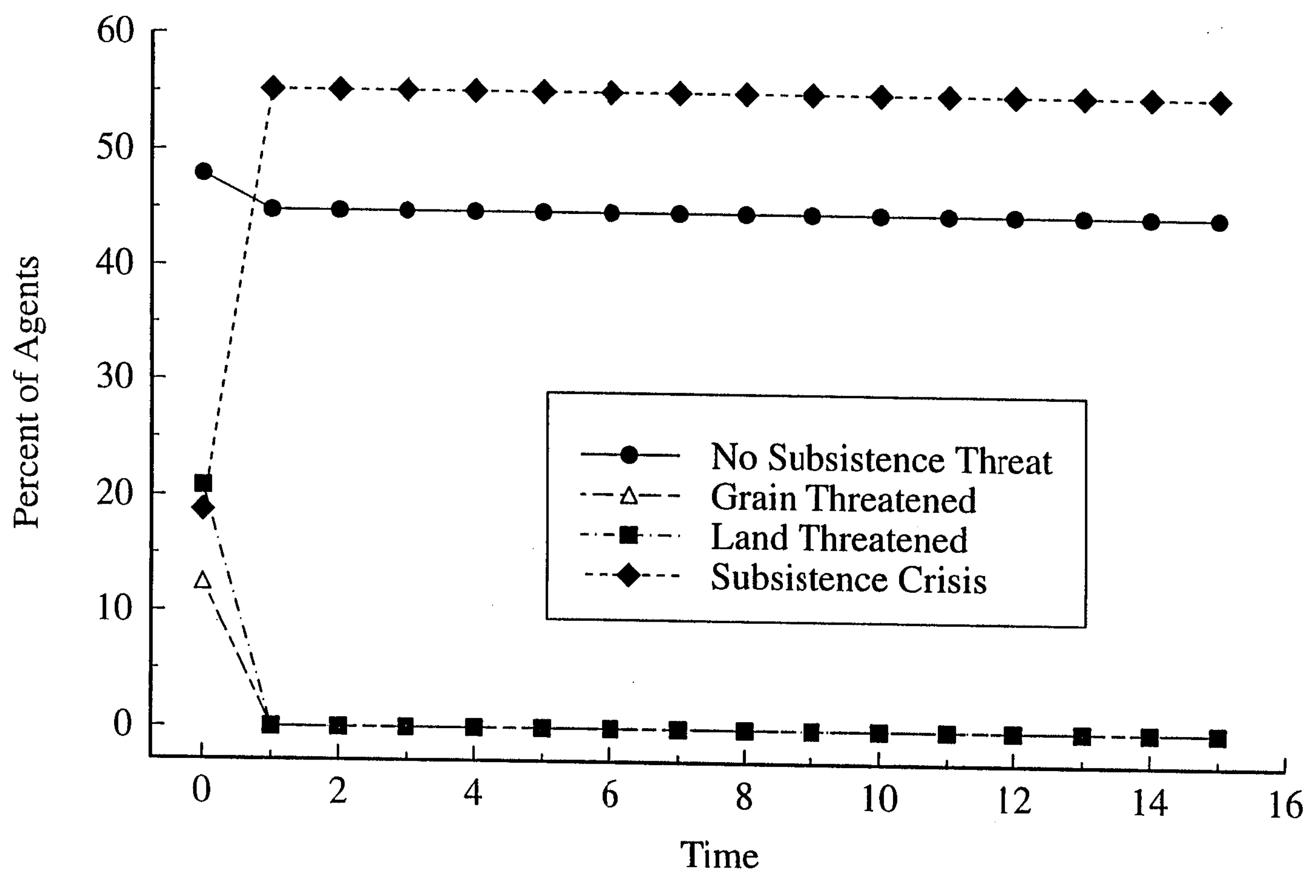
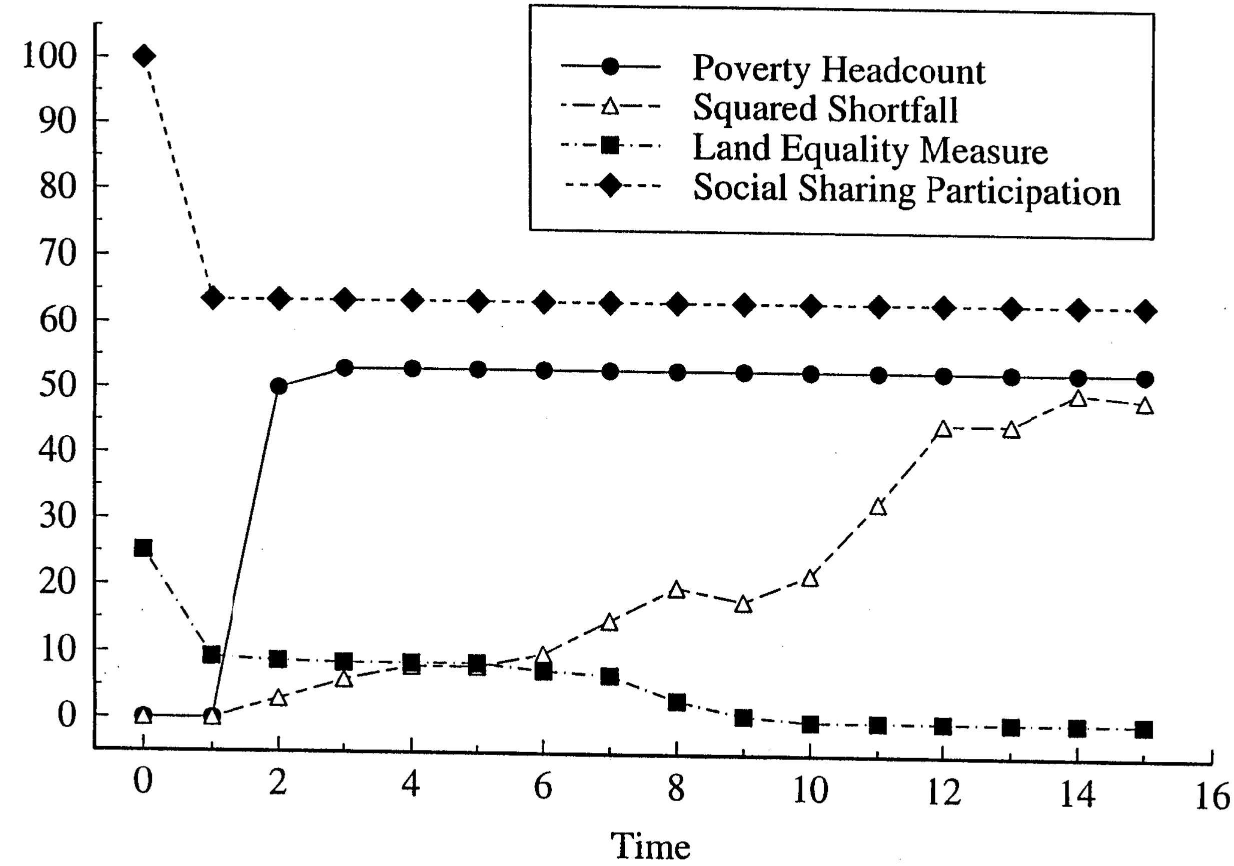


Figure 7: Evolution of Poverty and Inequality:
Social Sharing Case



subsistence crises, and strongly suggests a valuable economic role for social sharing norms in promoting food security.

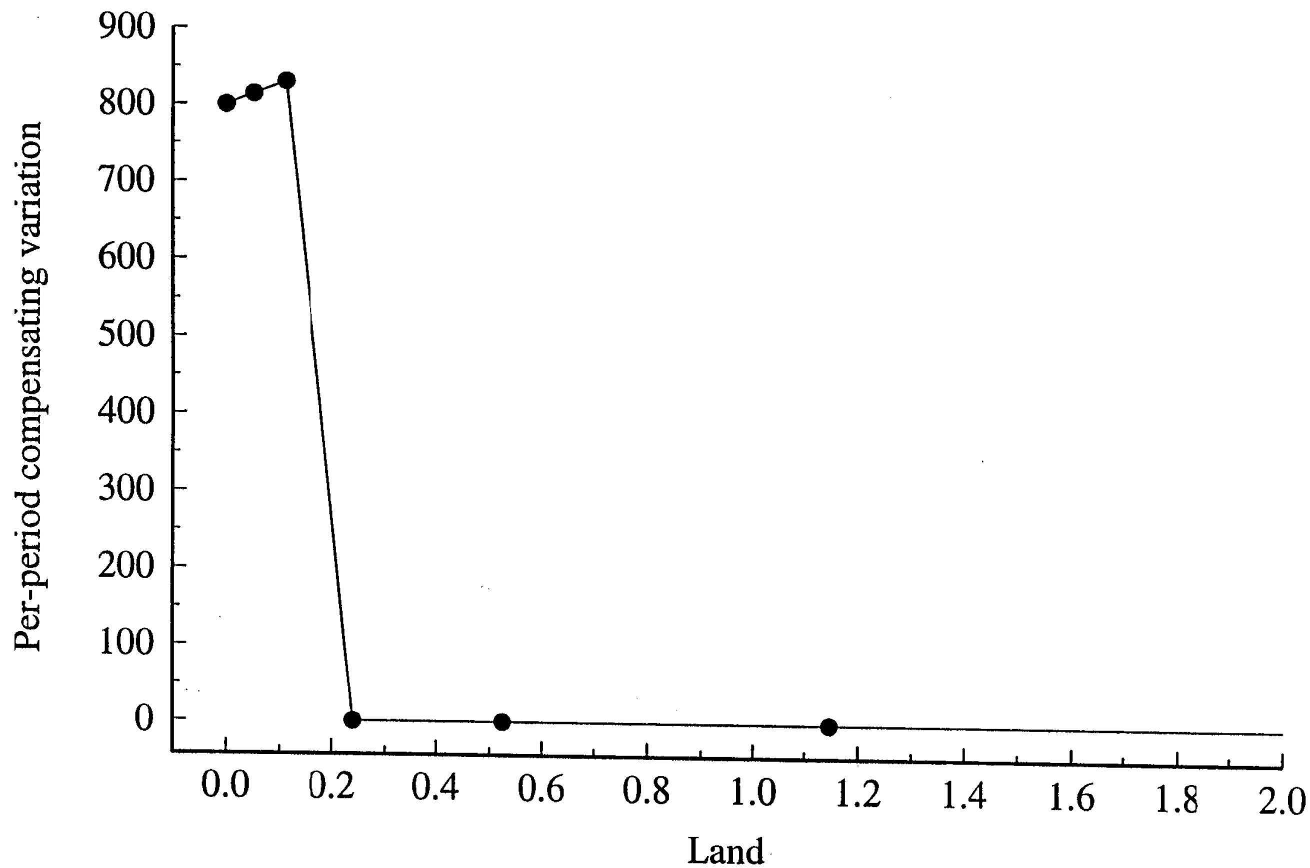
Section 6 Institutional Welfare Comparisons and Policy Implications

The preceding analyses of structural evolution under risk and alternative institutional arrangements have suggestive implications for public policy. At an individual level of analysis, the research presented here demonstrates that land is more than just a productive asset, but that it is reluctantly pressed into service by the poorest agents as a second-best risk-smoothing asset. Any policies--such as rural infrastructure improvement, irrigation programs, or extension services--which increase the shadow price of land to rural producers and hence tend to drive up its market price also improve its role as the last line of defense against subsistence shortfalls.

At the level of the aggregate distribution of rural assets, two fundamental long-term structural effects of production risk become clear. First, a class of agents exists whose initial endowments of land and grain or livestock are insufficient to guarantee their continued control over those endowments in a market economy under risk. These agents decumulate land under any institutional scenario that does not include direct transfers to them. Second, a class of agents exists who are menaced by the prospect of a possible consumption shortfall, but for whom such a shortfall is not inevitable. These agents accumulate grain as a consumption buffer against the vagaries of risky production. It is this group of agents for whom policies to mitigate the effects of risk are most relevant. These agents also comprise a large portion of the rural population in the sort of risky environments under study.

For this class of moderately risk-sensitive agents, a laissez-faire institutional environment is the worst scenario. Under it, agrarian structure rapidly evolves toward bimodalism, as some of the moderately risk-sensitive agents become increasingly risk-sensitive as successive or especially severe

Figure 8: Compensating Variation of the Social Sharing Scheme
(For Zero Grain Holdings)



adverse shocks impugn their stocks of stored grain, and reduce them to selling land to meet subsistence.

This is also the class which stands the most to benefit under the social sharing arrangement, which protects their consumption and asset endowments at least for a short time by taking up the risk-buffering role that would otherwise be played by their land endowments. But while the social sharing scheme is thereby successful in softening the pain in the short run of structural evolution, the force of this evolution proves in the end to be too powerful to conjure. The need for incentive compatability becomes more and more pressing as some agents are able to buy up land to become ever more independent of the reciprocal logic of customary risk coping.

While the social sharing scheme is thus able to put a human face on the ineluctability of risk-driven bimodalism, it cannot change the eventual structure of endowments, as the moderately risk-sensitive are forced back upon the less attractive risk-coping potential of stored grain.

The prospects for this intermediate class of rural producers might be somewhat better, however, if they could be offered a better, but still actuarially fair insurance asset. Specifically, the possibility of purchasing rainfall insurance would constitute a financial instrument whose advantage would derive from a return that is not just independent of, but actually negatively correlated with, returns to land. Where grain stocks provide portfolio diversification incidentally, by guaranteeing an approximately unvarying return, a rainfall lottery would serve a risk-specific role: its returns (still of zero mean) would be inversely related to those of land. Farmers could therefore limit their risk exposure to the unobservable, idiosyncratic component of their shock. While this risk would still be important, it would be less than that to which they are exposed under a laissez-faire policy environment, and more stably so than under the social sharing program.

Those agents who are moderately sensitive to environmental risk could protect themselves against it by investing in the rainfall lottery: their stored grain would in effect be converted every year into an optimal risk-coping asset, allowing them to trade back to a higher mean return on asset holdings, without paying the price of higher variance[6]. A rainfall lottery, i.e., an actuarially fair insurance scheme whose average payoff is zero, but whose per-period payoff is inversely correlated with village-level shocks, accordingly holds some promise for attenuating the severity of endogenous structural differentiation.

[6]The improved private risk-coping abilities associated with this insurance medium would increase the shadow price of land, both to this marginally sensitive group of agents as well as to wealthier agents. The resulting upward pressure on the land price would in turn benefit the subsistence-constrained group of agents, who employ land in part as a consumption-buffering store of value.

Appendix A

Parameterization of the Model based on the ICRISAT Burkina Faso Data.

The Data from Burkina Faso were collected from 1981-1985 by the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT). The survey encompassed six sample villages from three different agro-climatic regions of Burkina Faso, and is one of the largest and most comprehensive datasets collected on West African agricultural production. The survey results are well-suited for a basic parameterization of the model. The three regions are the Sahel, around Djibo, in the North; the Sudano-Sahel, around Yako; and the Guinea-Savanna, around Boromo. These regions vary considerably: Djibo is situated in a low-rainfall area where there are few trees and subsistence millet farming and itinerant cattle-herding dominate the agrarian economy. Boromo, by contrast, lies in the heart of the water-rich Burkinabè cotton belt, where corn, sorghum, and groundnuts are grown in relative abundance in addition to the cash crop, cotton. Yako lies between the other two, both geographically and in terms of its cropping system.

Asset Distributions

Table A-1 presents the land distributions for survey villages in the three regions. Note that the Yako villages exhibit the most equitable distribution of land, whereas, the Djibo and Boromo villages are more unequal. These distributions attempt to adjust for land quality differences where topography and placement (near or distant from the household compound) are concerned. Data on soil fertility were not recorded, and although different types of soil were recorded, there are so many soil types, and so few (relatively) fields, that a correlation between a soil type and its impact on land fertility was impossible to identify. It cannot be ruled out, therefore, that, especially in the north, the unequal land distribution is a reflection of the fact that some households have large amounts of relatively unproductive land, while others have smaller areas of highly productive land. Table A-2 presents the distribution of livestock and pension payments. Unfortunately, stored grain and cash savings were not recorded in the dataset. Nor were there sufficient observations on livestock holdings to permit the identification of a distribution of livestock holdings for each region separately, evaluated in CFA Francs at market prices. Because of the missing stored grain data, it was assumed that accounting for stored grain would about double households' overall asset holdings.

Table A-2: Distribution of Livestock and Pensions

dValue of Livestock, Pensions Francs CFA	Proportion
0 - 5000	.049
5000 - 25000	.146
25000 - 50000	.146
50000 - 100 000	.110
100 000 - 150 000	.134
150 000 - 250 000	.146
250 000 - 500 000	.085
500 000 - 1 m	.098
1 m - 2.5 m	.049
2.5 m - 3.75 m	.024
> 3.75 m	0

The data show almost no correlation between land holdings and livestock. A simple OLS regression of livestock holdings on land had an R^2 of .002.

Production Parameters.

The production parameter was estimated by computing mean yield. Again because of the variations in agroclimatic conditions across the different regions, these estimates were done separately for each region and crop. The mean yield for maize was considerably higher than

Table A-1: Distribution of Land per Household

Ha.'s	Djibo	Yako	Boromo
0 - 0.5	.118	.007	.162
0.5 - 1.0	.059	.054	.147
1 - 2	0	.101	.074
2 - 3	.059	.229	.103
3 - 5	.059	.322	.103
5 - 8	.176	.195	.147
8 - 12	.294	.067	.103
12 - 20	.235	.027	.147
> 20	0	0	.015

that for sorghum and millet, doubtlessly because of the special conditions under which maize is so often grown (on small plots close to the house, benefitting from manure and even chemical fertilizers). Mean yields for sorghum and millet were about 1250 kg./ha. for the Boromo and Yako areas, and about 650 kg./ha. for the far North.

Labor hours hover around 2500 hrs. per household production unit. Taking this figure to represent the effort of four adult-equivalent workers per year, subsistence requirements can be estimated to average 1000 kg. per year. Different household size was accounted for by normalizing land and livestock holdings to holdings per household member.

All of these figures are deflated by the numeraire, the food price, which averages 50 Francs/kg.

Risk Parameters

Carter (1991) uses the same ICRISAT dataset to estimate production risk in both the Sahel region and the wetter Guinea-Savanna region. The risk parameterization of the model is a reasonable approximation of his findings.

Table A-3: Risk Structure

Village-level shock Θ_v

Individual shock: Θ_i	Low $\Theta_v=.75$ p=.3	Medium $\Theta_v=1$ p=.4	High $\Theta_v=1.25$ p=.3
Low p=.2	$\Theta_i=.9$ $\Theta_i\Theta_v=.675$ $p_{cell}=.06$	$\Theta_i=.8$ $\Theta_i\Theta_v=.8$ $p_{cell}=.08$	$\Theta_i=.7$ $\Theta_i\Theta_v=.875$ $p_{cell}=.06$
Medium p=.6	$\Theta_i=1$ $\Theta_i\Theta_v=.75$ $p_{cell}=.18$	$\Theta_i=1$ $\Theta_i\Theta_v=1$ $p_{cell}=.24$	$\Theta_i=1$ $\Theta_i\Theta_v=1.25$ $p_{cell}=.18$
High p=.2	$\Theta_i=1.1$ $\Theta_i\Theta_v=.825$ $p_{cell}=.06$	$\Theta_i=1.2$ $\Theta_i\Theta_v=1.2$ $p_{cell}=.08$	$\Theta_i=1.3$ $\Theta_i\Theta_v=1.625$ $p_{cell}=.06$

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